Nature Environment and Pollution Technology
An International Quarterly Scientific Journal
p-ISSN: 0972-6268 (Print copies up to 2016)
e-ISSN: 2395-3454
Vol. 24 No. S1 pp. 41-62 2025
Original Research Paper
https://doi.org/10.46488/NEPT.2024.v24iS1.003
Open Access Journal

Environmental Impact Assessment of Air Quality Issues Caused by the Granite Quarrying and Stone Processing Industry in Ramanagara District, Karnataka State, India

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Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 30-04-2024
Revised: 06-06-2024
Accepted: 19-06-2024

Key Words:
Environmental Impact Assessment
Granite quarrying
Stone processing
Air quality
Pollutants
Health

ABSTRACT

The environmental impacts of mining, quarrying, and the stone processing industry are significant, affecting air quality, health, and the socioeconomic status of communities worldwide. Key contributors to air pollution include the waste of raw materials from quarrying, non-compliance with scientific protocols, and the extraction of natural mineral resources. The rapid increase in pollution sources, such as dust, water, and noise, has led to the release of various pollutants into the atmosphere, degrading local air quality. This study conducted sampling at twelve sites, adhering to the Central Pollution Control Board's (CPCB) monitoring guidelines. Twelve metrics, including PM_{10}, $PM_{2.5}$, SO_2, NOx, CO, O_3, Pb, NH_3, C_6H_6, C_2OH_{12}, As, and Ni, were measured twice a week over a three-month period (January 2024 to March 2024) by the National Ambient Air Quality Standards (NAAQS) in the research area. The results indicated that while SO_2 and NOx levels were within permissible limits at all monitored locations, Suspended Particulate Matter (SPM) levels were high at every station. The average baseline levels of PM_{10} (37.17 μg/m³ to 70.52 μg/m³), $PM_{2.5}$ (16.98 μg/m³ to 39.85 μg/m³), SO_2 (5.29 μg/m³ to 13.91 μg/m³), NOx (9.8 μg/m³ to 29.71 μg/m³), CO (0.15 mg/m³ to 0.32 mg/m³), O_3 (6.9 μg/m³ to 15.37 μg/m³), and NH_3, Pb, Ni, As, C_2OH_{12}, and C_6H_6 were below the detection levels (BDL) and limits of quantification (LOQ), all within the National Ambient Air Quality Standards for commercial, industrial, and residential areas during the study period. This research highlights the urgent need for effective pollution control measures to mitigate the adverse environmental and health impacts of these industries.

INTRODUCTION

Quarrying is the process of extracting minerals from the upper crust of the earth. The natural resources of the world, including land, soil, air, dust, noise, water, the biosphere, human health, society, and the socioeconomic status of the populace, are severely being harmed by the quarrying and stone processing industries (Gbeve 2013, Emmanuel 2018, Umar et al. 2023). This is because there are no scientific techniques for managing granite reserves and resources, and they are overexploited by humans (Vallack et al. 1998, Ukpong 2012, Sreekala et al. 2023). In addition to air, noise, dust, and water pollution, land degradation, biodiversity loss, topographical relief, flooding, extremely cold temperatures, forest fires, changes in the climate and seasonal pattern variation, greenhouse effects, and health risks from drilling, blasting, and ground vibration, we are currently dealing with serious environmental issues (Singh et al. 2010, Jahed Armaghani et al. 2015, Kittipongvises 2017).

For four or five centuries, natural resources have been overexploited without regard for the consequences to the ecosystem, which has led to these problems (Sheikh et al. 2011, Melodi 2017). The most damaging human activities are those that harm the ecosystem both immediately and over time (Mwangi 2014, Ming'ate et al. 2016). The environment is seriously threatened by overexploitation and negligent practices in the mining and stone processing industries (Odewumi et al. 2015, Okafor et al. 2023).

The primary environmental effects of granite quarries were the creation of artificial ponds, isolated artificial reliefs, regular-shaped depressions, erosion and instability of quarry scarps, partial or total destruction of fluvial terraces, piezometric surface depression, altered groundwater flow direction, formation of periodically flooded areas, permanent removal of areas from agricultural use, changes to farming practices, and pedological changes in soil (Oyinloye et al. 2015, Kofi-Boye 2017, Leon-Kabamba et al. 2020, Rathore 2020, Roja 2022). To ensure that these regions can eventually be exploited again, people should work toward degraded environment regeneration at every stage of quarrying activities (Saha et al. 2011, Santizo 2022).

The surrounding landscapes of quarrying places are severely impacted by the difficulties in disposing of waste rock (Singh et al. 2010, Sayara 2016). A significant global concern, aside from the granite industry, is human-caused air pollution (Singhal 2018, Salem 2021, Sreekala et al. 2023). Understanding the ways that metropolitan areas impact the chemistry, composition, and life cycles of the atmosphere in several hundred-kilometer downwind regimes can be achieved by considering them as concentrated sources of massive anthropogenic emissions of pollutants (Yeh et al. 1980, Ajibade et al. 2022). Additionally, research on the global epidemiological impacts of air pollution has demonstrated that particulate matter and gaseous pollutants can seriously impair human health, leading to respiratory disorders, heart disease, and cardiopulmonary death (Abdul-Wahab et al. 2015 & 2022, Zimwara et al. 2021).

Fossil fuels and their derivatives are being used more frequently as a result of emerging countries' increasing industry, urbanization, technological innovation, and modernization (Ajah et al. 2018, Zimwara et al. 2021). Thus, the primary challenge facing emerging nations is reducing air pollution, particularly in quickly expanding megacities (Daspan et al. 2018). Estimates from the World Health Organization indicate that air pollution causes nearly two million premature deaths annually, including lung infections, heart attacks, respiratory diseases, and even cancer (Haseeb 2018, Werner et al. 2019). The use of fossil fuels with poor environmental performance, improper land use patterns, industrialization, fast population growth, an increase in vehicles, inadequate transportation infrastructure, improper land use patterns, and-most importantly-ineffective environmental regulations are some of the factors contributing to India's rising air pollution levels (Chattopadhyay et al. 2010, Henry et al. 2017).

The World Health Organization's (WHO) recommended health thresholds for air pollution are exceeded in the majority of Indian cities with populations greater than two million people (Halwenge 2015, Martins et al. 2017). With the aid of remote sensing and GIS software, monitoring the concentrations of various ambient air quality indicators not only prevents detrimental health effects but also provides policymakers with a foundation for successful environmental regulations (Moeletsi 2018, Werner et al. 2019). SPM (suspended particulate matter), SO_2 (sulfur dioxide), and NOx (nitrogen oxide), together with other chemicals generated by numerous businesses, particularly the granite industry, are the main pollutants causing environmental destruction in the area. Reduced plant photosynthesis, noise and dust pollution, structural flaws, biodiversity loss, and nuisance dust are only a few of the problems that quarrying is frequently linked to (Nandan et al. 2017, Omeiza et al. 2022).

People's property and health are being significantly impacted by industrial site noise, ground vibrations, drainage, and particulate matter (Sunyer 2001, Stieb et al. 2005). Potential effects of these include decreased agricultural productivity, significant harm to the region's road network, and environmental issues such as soil erosion, vegetation loss, building fissures, biodiversity loss, and topographical changes (Sun et al. 2016, Sayara et al. 2016). Because it generates a variety of contaminants, the granite quarrying and processing industry is dangerous (Tsiouri et al. 2015).

Today, those who live near quarries have extremely terrible lives as a result of pollution. Health problems can affect anyone at any moment; respiratory and skin conditions are two examples (Zanobetti et al. 2009, Yakovleva 2017). The term "AQI" (air quality index) is used because it is challenging to provide high-quality data regarding the concentration of several environmental indicators (Wright 2009, Trivedi et al. 2009 & 2010). The common spaces and woodlands of the communities are covered in waste material, often known as by-products (Yasobant et al. 2017, Abeya 2023).

A significant amount of inert dust is discharged into the sky during the quarrying process, and depending on the wind direction, this dust can travel up to 4 or even 5 kilometers (Chowdhury 2004, Aarthy et al. 2018). This causes cloudbursts, which in turn cause downpours and flash floods by preventing the formation of rain clouds (Ekpa et al. 2022 & 2023). Because it entails the direct exploitation of resources, quarrying is distinct. It supplies the building sector with raw materials. The construction sector needs a lot of stone for its projects. The increasing need for building materials, including aggregate, sand, gravel, and rocks, as well as industrial manufacturing, is driving the market for quarry commodities. This leads to the mismanagement of natural resources, which is detrimental to the ecology and economy.

The objective of the current study is to assess how the granite quarrying, stone-cutting, crushing, and stone-processing activities that are conducted in the study region affect the local environment. The state of Karnataka is home to most of the rich mineral and ore resources, such as bauxite, iron, manganese, gold, copper, and some significant rocks like gneiss, granite, granodiorites, and doleritic dykes.

The Ramanagara region of Karnataka State's granite quarries are the subject of this study's environmental effects. To develop mitigation and control techniques, the research

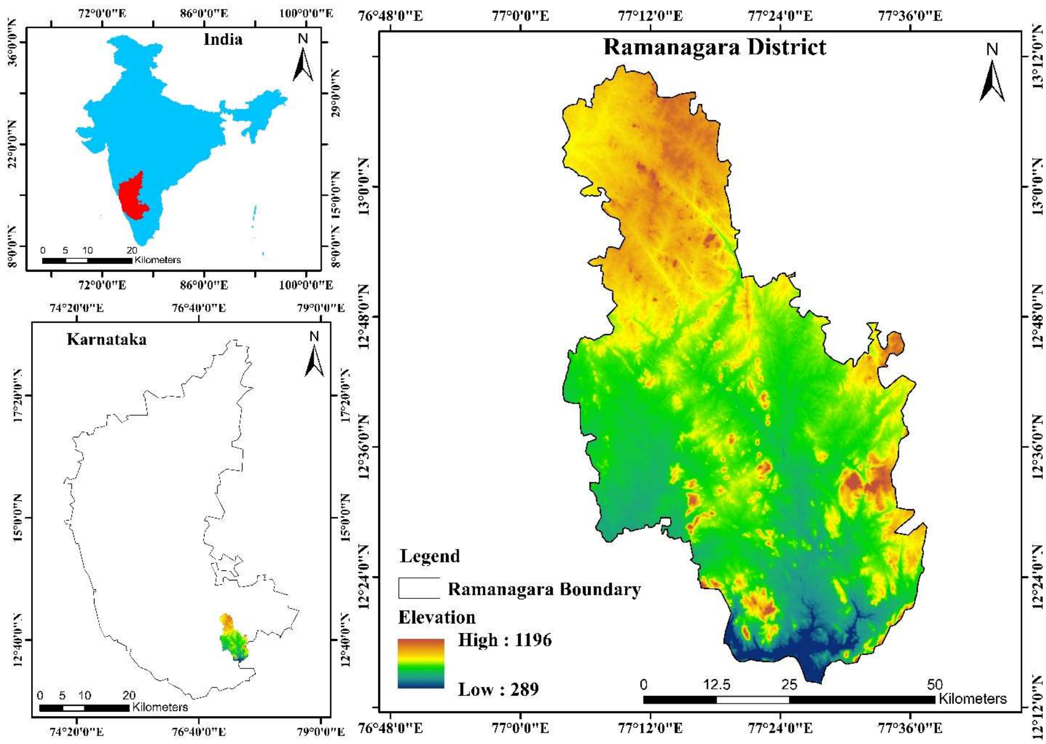

Fig. 1: Study region with data on elevation.

will gather and analyze air samples, calculate their impact on air quality in residential, industrial, and quarry contexts, and use the results. This research will help future researchers and add to the body of information about the quarrying business. In this district, the local inhabitants and the environment are being negatively impacted by the stone processing and quarrying businesses.

STUDY AREA

On August 23, 2007, the former Bengaluru Rural District-which included the taluks of Ramanagara, Channapatna, Kanakapura, and Magadi-was divided into the Ramanagara district. According to Bhat et al. 1991 & 1994, and Swamy 1998, its largest lengths are 102.25 kilometers in the north-south direction and 62.08 kilometers in the east-west direction. The district is composed of 823 settlements spread over a 3516 km^2 physical area, of which 699.46 km^2-or around 17.21% of the district's total area-are forest. The district's headquarters are in the town of Ramanagara, which is situated roughly 50 miles southwest of Bengaluru, the state capital.

The district of Ramanagara is located between latitudes 12.72°N and 77.27°E. Fig. 1 shows the contour lines that delineate the district's most notable high and low elevation zones, which are located at elevations of 1196 and 289 meters above mean sea level, respectively. There are 742.50 meters above sea level on average. The district borders Mandya on the west, Bangalore Urban on the northeast, and Tumakuru, Bangalore Rural, and Bangalore Urban on the north.

MATERIALS AND METHODS

Materials

The toposheet was used in this study to derive the morphological area. Toposheet numbers are compiled by the Indian government's Survey of India (SOI). D43R4_57G4, D43R8_57G8, D43X1_57H1, D43X2_57H2, D43X3_57H3, D43X5_57H5, D43X6_57H6, D43X7_57H7, D43X8_57H8, D43X9_57H9, D43X10_57H10, and D43X11_57H11 are some instances of toposheet numbers.

Elevation and land cover data are obtained from DEM Cartosat-1 and LISS satellite photos on the ISRO Bhuvan website. The meteorological and air quality data sets come from a field investigation, a few official technical publications, and the Open Government Data (OGD) platform in India. Several government bodies, such as the Department of Mines and Geology (DMG) and the Ramanagara district mineral survey report, have provided reports and information about quarrying. Table 1 indicates these data sets.

Table 1: Datasets utilized in the field investigation

Data name	Resolution	website
DEM	10m	Indian Geo platform (Bhuvan)
LISS 3	30m	Indian Geo platform (Bhuvan)
Landsat 8	30m	USGS
Toposheets	1:50000	SOI(survey of India)
Rainfall and temperature	0.5*0.5 km	IMD(India meteorological department)
Quarry and rocks	-	DMG(department of Mines and Geology
Air quality	-	open governmental data (OGD) platform, India

Methodology

Compiling information from many sources: Primary and secondary sources served as the foundation for this investigation. Field and market surveys, maps, questionnaires, interviews, and laboratory tests are examples of primary sources. Books, journals, published and unpublished reports, and official government documents are examples of secondary sources. The effects of air pollution on the local ecology, people, flora and wildlife, crops, and surroundings were evaluated using field surveys and general observations. The Ramanagara district of the Indian state of Karnataka, which is renowned for its rich granite deposits, diversity, and amount of forest cover, is the only area covered by the study. Using a systematic and random selection process, a sample of the homes at the randomly selected quarry sites was created, resulting in the sample households.

The sample consisted of only one or two hundred adjacent towns or residences that are both directly and indirectly affected by the quarrying activity. Field research and a standardized questionnaire were used to collect data from the families. A research study report was prepared for the analysis in the Ramanagara district locations using baseline data collected at many sites throughout a single season (January 2024 to March 2024). The data are shown in Table 2. These figures were used to assess the possible harm caused by the stone-processing and quarrying industries. They provided guidance on the best course of action for the quarry site and industry, as well as resources for management, government organizations, and mitigation strategies. For this research project, the findings of the analysis report and study summary were carefully considered.

Choosing study sites for the sampling process: Table 3 shows the location, with sampling locations labeled in different environmental settings. Climate data, topography and terrain, human settlements, health status, accessibility to the monitoring site, resource availability, representativeness of the region for establishing baseline status, and representativeness about likely impact areas were taken into account when choosing the locations for ambient air quality monitoring.

Guidelines for collecting ambient air quality samples: For three months, ambient air quality was monitored twice a week in each region. The following parameters were used to create baseline data for the air environment: lead (Pb), arsenic (As), nickel (Ni), free silica, benzene (C_6H_6), Benzo (a) pyrene C_2OH_{12}, ammonia (NH_3), ozone (O_3), nitrogen dioxide (NO_X), sulfur dioxide (SO_2), carbon monoxide (C_O); particulate matter ($PM_{2.5}$), and (PM_{10}) size less than 10 µm. A comparison has been conducted between the national ambient air quality guidelines and the measured concentrations of pollutant parameters.

Equipment for gathering samples: Particulate matter (PM_{10} and $PM_{2.5}$) was detected using Envirotech 271; combo PM_{10} and $PM_{2.5}$ samplers; breathable dust samplers (Envirotech APM 460 BL); and fine particulate samplers (APM 550). Gaseous pollutants, such as SO_2, NO_X, O_3, and NH_3, were sampled using Ecotech's AAS 109, Envirotech's APM 411, and Ecotech's APM 460 gaseous pollution samplers. Electrochemical sensor technology was used for carbon monoxide monitoring. Every year, the monitoring instruments need repairs and calibrations.

Techniques for analysis and sampling: Table 4 enumerates the sampling and analytical methods utilized to track ambient

Table 2: Parameter derived from multiple sources

Sl. No.	Attribute	Parameter	Source of Data
1.	Climatology and Meteorology	Wind speed, Wind direction, Dry bulb temperature, Wet bulb temperature, Relative humidity, Rainfall, Solar radiation, Cloud cover and Environmental Lapse.	Field research, collecting data from a variety of locations, including industrial, residential, and quarry sites.
2.	Geology, rock and Soil	Geological history	Field research, Primary and secondary sources, satellite photos, topographical maps, etc.
3.	Ambient Air Quality	PM_{10}, $PM_{2.5}$, SO_2, NOx, Pb, CO, O_3, C_6H_6, As, Ni, NH_3, C_2OH_{12}, Free Silica etc.	Monitored Data (12 locations)

Table 3: Location and the gathering of samples in various environments

Location Code	Sample code	Locations	Latitude	Longitude	Distance (km) from Ramanagara town	Azimuth Directions	Environmental setting
QL 1	AAQ1	Doddamudawadi quarry site	12°37’38.08” N	77°22’47.27” E	15.74	SE	Commercial
QL 2	AAQ2	Yadamaranahalli quarry site	12°24’54.09”N	77°22’56.53”E	35.54	S	Commercial
QL 3	AAQ3	Hanakadaburu, kodi-halli hobali quarry site	12°24’17.24”N	77°32’50.28”E	45.4	SE	Commercial
QL 4	AAQ4	Hanakadaburu, kodi-halli hobali quarry site	12°23’49.59”N	77°32’39.51”E	46.58	SE	Commercial
QL 5	AAQ5	Achalu quarry site	12°27’55.43”N	77°21’18.06”E	30.37	S	Commercial
QLV 6	AAQ6	Hanakadaburu village	12°24’1.12”N	77°32’51.18”E	46.5	SE	Residential
QLV 7	AAQ7	Kodahalli village	12°25’9.41”N	77°18’34.70”E	33.66	SW	Residential
QLV 8	AAQ8	Achalu village	12°28’30.11”N	77°21’47.08” E	28.55	S	Residential
QLV 9	AAQ9	Harohalli village	12°40’53.59”N	77°28’26.33”E	21.3	SE	Residential
QLV 10	AAQ10	Bidadi village	12°47’56.48”N	77°23’9.77”E	15.67	NE	Residential
QLIN 11	AAQ1I	Harohalli Industrial area	12°41’0.05”N	77°26’43.60”E	18.27	SE	Industrial
QLIN 12	AAQ12	Bidadi industrial area	12°47’54.84”N	77°23’0.33”E	14.51	NE	Industrial

Table 4: Techniques for data analysis for ambient air quality parameter Assessment (NAAQS).

Sl. No.	Parameters	Analytical method	NAAQ standards: 2009	
1.	Sulphur Dioxide (SO_2), μg/m^3	IS: 11255 (Part 2)/USEPA Method 6	50 (Annual)	80 (24 Hours)
2.	Nitrogen Dioxide (NO_2), μg/m^3	IS: 5182 (Part - guidelines Volume1 6): 2006 /CPCB	40 (Annual)	80 (24 Hours)
3.	Particulate Matter ($PM_{2.5}$), μg/m^3	In house method (Gravimetric method) based on CPCB guidelines Volume1	40(Annual)	60 (24hours)
4.	Particulate Matter (PM_{10}), μg/m^3	IS:5182 (Part–guidelines Volume1 23): 2006/CPCB	60 (Annual)	100 (24 hours)
5.	CO, mg/m^3	IS:5182(Part–10):1999(Reaff:2006) CPCB guidelines Volume1	2 (8 hours)	4 (1hour)
6.	Pb, μg/m^3	IS:5182(Part–22):2004(Reaff:2006) CPCB guidelines Volume1	0.5 (Annual)	1 (24 hours)
7.	O_3, μg/m^3	In house method (Spectrophotometric method) based on CPCB guidelines Volume1	100 (8hours)	180 (1hour)
8.	NH_3, μg/m^3	In house method (Spectrophotometric method) based on CPCB guidelines Volume1	100 (Annual)	400 (24 hours)
9.	Benzene, μg/m^3	GC FID/ GC MS based on IS 5182 (Part:12) / CPCB guidelines Volume1	5 (Annual)	5 (Annual)
10.	Benzo (a) pyrene, ng/m^3	In House Validated Method By HPCL, UV and GC MS Based on IS:5182(Part– 12) CPCB guidelines Volume1	1 (Annual)	1 (Annual)
11.	Arsenic, ng/m^3	In house method (AAS method) Based on CPCB guidelines Volume 1	6 (Annual)	6 (Annual)
12.	Nickel, ng/m^3	In house method (AAS method) Based on CPCB guidelines Volume 1	20 (Annual)	20 (Annual)

air quality. The closest power sources, which included homes at each AAQ station or governmental entities including Panchayat offices, schools, and temples, were used to power the AAQ equipment.

Table 5 displays the frequency and techniques of monitoring. The analysis report and summary of the air quality survey results were carefully considered for this study project.

Table 5: The frequency and monitoring techniques.

Attributes	Sampling		Measurement Method	Remarks
	Network	Frequency		
Meteorology				
Wind speed, Wind direction, Dry bulbtemperature, Wet bulb temperature, Relativehumidity, Rainfall, Solar radiation, Cloud cover and Environmental Laps	Selected locations	Continuous for 3 Months	Weather monitorswith the database	As per Meteorological department standard. Primary or secondary data
Air Environment				
Particulate Matter (PM_{10})	Selected locations	24 hourly-Twice a week for 3months in non-Monsoon season	Gravimetric (High-Volume with Cyclone)	As per CPCB standards under 18th November 2009 Notification for NationalAmbient Air Quality Standards (NAAQS). Field survey, Primary or secondary data
Particulate Matter ($PM_{2.5}$)			Gravimetric (High-Volume with Cyclone)	
Oxides of Sulphur (SO_2)			EPA Modified West and Gaeke method	
Oxides of Nitrogen (NOx)			Arsenite Modified Jacob and Hochheiser	
Carbon Monoxide (CO)			Gas Analyzer (NDIR)	
Ozone (O_3)			UV photometric	
Ammonia (NH_3)			Indophenol Blue Method	
Lead (Pb)			Atmospheric Absorption Spectrometer	
Arsenic (As)				
Nickel (Ni)				
Benzene			GC-MS/MS	
Benzo Alpha Pyrene			GC-MS/MS	

RESULTS AND DISCUSSION

The Geological Setting of the Granite Quarry in the Study Area

The Ramanagara district's geology: According to Bhat et al. (1994), Syed Abrar et al. (2000 & 2005), Swamy (1998), the rocks in the district come from the Sargur group, the Peninsular Gneissic Complex (PGC), the Charnockite group, the Closepet granite, and the basic and more recent intrusive. The Charnockite group's representative is Charnockite. Lenses found in gneisses, migmatite, amphibolite, and banded magnetite quartzite, which appears as tiny bands—are all part of the Sargur group. Granites, gneisses, and migmatite make up the PGC, which is situated east and west of the Closepet granite (Bhat et al. 1991 & 1994, Simha et al. 2015, Venkatesha et al. 2015). Within the gneisses, the intrusive bodies containing the Closepet granite stretch 50 km in length and 15-20 km in width, with a near-N-S trend. There are reported to be enclaves of migmatite, gneisses, quartzite, and amphibolites among the various compositions found in the Closepet granite. The common intrusives are dolerite, gabbro, pyroxenite, and rarely norite. Dolerite is the most common of the fundamental dikes (Paranthaman et al. 1995, Swamy 1998, Syed Abrar et al. 2000 & 2005). Three main lineaments in the district go to NNW-SSE. These lineaments range in length from 45 to 70 kilometers. According to the interpretation of this data, a deep-seated fault that is trending NNW-SSE crosses the Closepet granites (Suresh Babu 1995).

The main land uses in the areas covered by quarry leases are plan land, hills, vegetation, various rock formations, and soil cover or overburden. Pebbles are most common in low-lying, loose soils, and most of the leased areas have thin patches of dirt covering them that are between 0.5 and 10 meters thick. Both on higher ground and in deposits at the surface, there are rock outcrops. Reddish-brown soil capping covers the majority of the hill's northern, western, and eastern sections at the lower elevation of the quarry lease area.

The field investigation's findings indicate that the geological setting of the granite quarry area is influenced by several variables, such as the quarry's topography, size, potential deposit formation type, material quality, mineral structure and texture, color, and chemical makeup, as well as the availability of resources, the company's financial standing, the intended output, market, price, supply and demand, and so forth.

Table 6: Lithostratigraphy and rock types in Ramanagara District

Soil Clover	
I. **Younger intrusive** (More recent invasion)	Extremely potassic rocks; dolerite/gabber/diorite/norite dykes; felsite/felsite porphyry dykes; coarse-grained pink/grey porphyritic granite.
II. **Closepet granite (2400–2100 Million years)**	Pink/grey porphyritic granite with coarse grain; pink granites (less mafic); grey granites; pink hornblende granite; pink equigranular/porphyrite migmatites.
III. **Peninsular Gneissic Complex (3000 Million years)**	Grey migmatites, biotite gneiss, leucogneiss and homophonous gneiss, charnockite and migmatite.
IV. **Sargur group (> 3000 Million years)**	Garnet-sillimanite gneiss, quartzite (fuchsite and BMQ), meta-ultramafites, amphibolites (both massive and schistose), and banded magnetite quartzite.
Not visible is the base	

With an average thickness of fewer than 0.5 meters, the dirt in the middle of the ridge is only present in the spaces between the stones. The established stratigraphic succession of the research region is displayed here, based on fieldwork and observations. The rock types and lithostratigraphy of the Ramanagara District are depicted in Table 6.

The study area is situated in Seismic Zone III, which is characterized as having a very high potential for earthquake shocks of 5 or 6 on the Richter scale, and Seismic Zone IV, commonly known as the high damage risk zone.

In this district, sand mining and defined and non-specified minor mineral leases in Kanakapura, Ramanagara, Channapatna, and Magadi Taluk were conducted in parallel with taluk-wise quarrying operations for dimension stone, construction stone, brick earth, crushers, and stone cutting facilities. Moreover, the area has more crushing factories

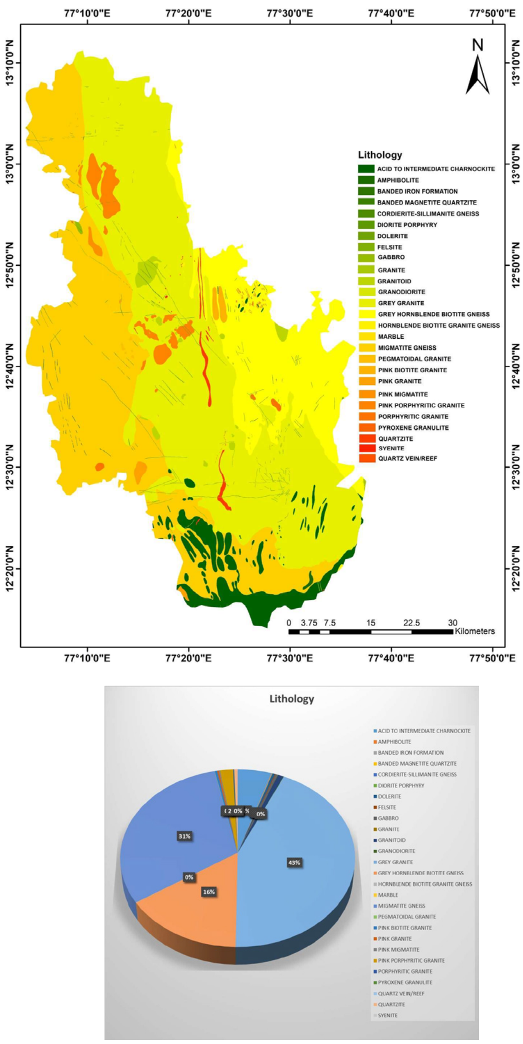

Fig. 2: Lithology and its percentage of Ramanagara district.

per square mile than other districts, and four to five decades ago; it was home to several granite quarries and crushing businesses.

The environment is contaminated by the stone-cutting and quarrying processes' noise, dust, water, and other factors. The associated radioactivity varies depending on the surrounding environment due to dust emissions from quarrying and crushing processes. Fig. 2 displays the lithology and area of the Ramanagara district.

Within the research region of the Ramanagara district, which spans a total geographical area of 3516.21 sq. km, various types of rocks are dispersed as follows: The region encompassed 173.6 sq. km of acid to intermediate charnockite; 3.12 sq. km of amphibolite; 4.24 sq. km of banded iron formation; 1.2 sq. km of banded magnetite quartzite; 0.3 sq. km of cordierite-sillimanite gneiss; 0.96 sq. km of diorite porphyry; 12.4 sq. km of dolerite; 3.26 sq. km of felsite; 12.82 sq. km of gabbro; 0.54 sq. km of granite; 29.36 sq. km of granitoid; 3.23 sq. km of granodiorite; 1522.9 sq. km of grey Granite; 545.83 sq. km of grey hornblende biotite gneiss; 0.69 sq. km of hornblende biotite granite gneiss; 0.59 sq. km of marble; 1080.64 sq. km of migmatite

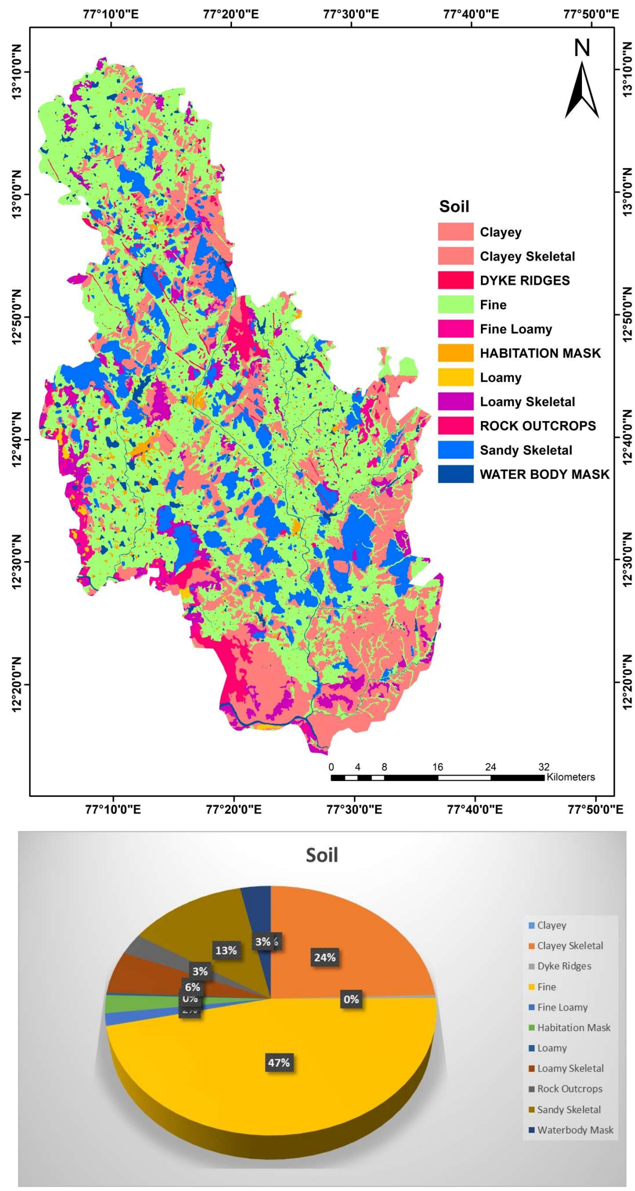

Fig. 3: Conditions of the soil and its percentage in the study area.

gneiss; 3.37 sq. km of pegmatoidal granite; 12.03 sq. km of pink biotite granite; 8.07 sq. km of pink granite; 6.92 sq. km of pink migmatite; 66.46 sq. km of pink porphyritic granite; 4.66 sq. km of porphyritic granite; 2 sq. km of pyroxene granulite; 0.23 sq. km of quartz vein/reef; 16.19 sq. km of quartzite; and 0.57 sq. km of syenite. The Ramanagara district is entirely covered in rocks. Gray granite and migmatite gneiss are the two main lithologies in this area. The region is roughly 1552 km^2 and 1080 km^2.

The Ramanagara District's Soil Type and Proportion Covered

Although dirt is essential to air pollution, it usually serves no purpose in the quarrying process or other associated operations. About 60% of the Ramanagara district is covered with red, sandy soil (Hema et al. 2012). The remaining soil is loamy and reddish-brown. Geology and soil are closely related in a pedogenic system because of the combined effects of parent material, climate, biosphere, terrain, relief, stage, age, maturity, and time of rock weathering conversion, rainfall, solar radiation, and management (enhancement and degradation/erosion). The main regions with red sandy soil include the taluks of Channapatna, Kanakapura, Magadi, and Ramanagara due to their varied topographies (Caruthers 1984, Hema et al. 2013, Ganesha et al. 2017). Fig. 3 list every type of soil.

With a total land area of 3516.21 sq. km, the Ramanagara district contains a variety of soil types that are scattered throughout the research region, including the following: 8.59.7 sq.km of skeletal clayey; 17.09 sq.km of dyke ridges; 1634.47 sq.km of fine; 54.79 sq.km of fine loamy; 81.91 sq.km of habitation mask; 12.23 sq.km of loamy; 192.06 sq.km of skeletal loamy; 98.34 sq.km of rock outcrops; 445.7 sq.km of sandy skeletal; 117.54 sq.km of water body mask of habitation.

The Methods Used in the Ramanagara District for Granite Quarrying Operations

In the Ramanagara district region, the majority of stone quarrying activities employ opencast extraction techniques. In open-cast quarrying, significant overburdens such as organic plant cover and topsoil must be removed to reach the

Table 7: Quarrying activities in the Ramanagara district areas leased by the government as of 2022-23.

Sl. No	Taluk	Building stone	Ornamental or dimension stone	Brick earth	Crusher Units	M-sand units
1	Ramanagara	38	02	-	29	08
2	Kanakapura	25	52	-	03	02
3	Magadi	19	04	O2	10	02
4	Channapatna	-	02	-	-	-
	Total	82	60	02	42	12

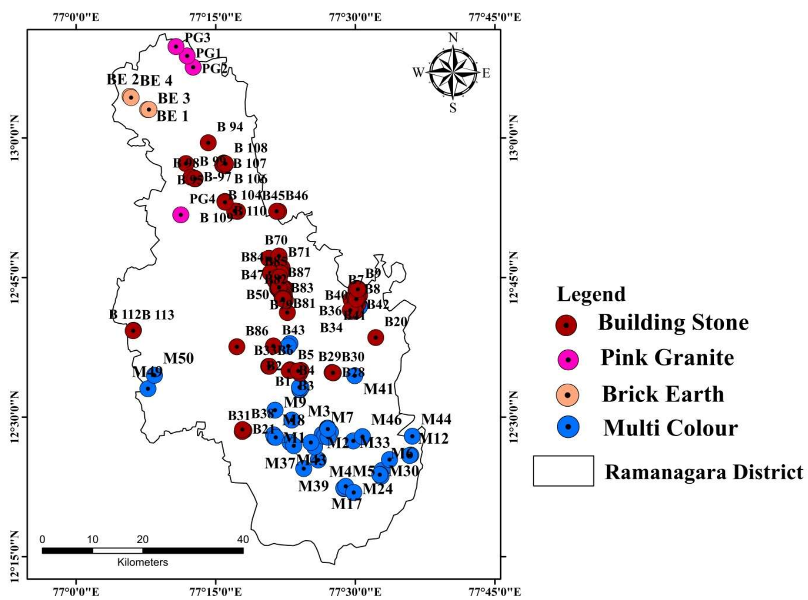

Fig. 4: Quarrying areas spreading in the Ramanagara district.

mineral reserves. The following procedures are involved in extracting granite through open-cast quarrying for dimension or ornamental stone: clearing the area, loading waste or well-dressed materials, transportation, processing raw materials, quality control, shifting, management of stockyards, and recycling waste materials as khandas or brick materials (Rajan Babu et al. 2000 & 2002 & 2003, Drew et al. 2002, Gbeve 2013, Eshiwani 2014,). Stone quarrying, stone crusher buildings, and sand mining are subject to additional operational limitations. There is evidence that these actions have a detrimental effect on the ecosystem.

There are various phases of quarrying operations, and each one has a unique impact on the environment. These phases typically entail deposit exploration and prospecting, the development and preparation of quarries, the use of materials from the quarries, and the processing of the minerals collected at the various installations to create products that may be marketed (Chalekode 1978, Kuzu et al. 2005, Ibrahim et al. 2018, Chaanda et al. 2019). However, there are numerous other environmental risks associated with open-cast quarrying practices. As of 2022–23, Table 7 indicates that the following Ramanagara district lands have been leased by the government (department of mines and geology) for quarrying purposes. Fig. 4 shows the quarrying areas spreading in the Ramanagara district.

Quarry Rock has the third and fourth positions in the world's non-fuel mineral commodities value and volume rankings. However, the quarry's operations deteriorate the land's condition and raise air pollution levels, which negatively impacts the neighborhood's residents and workers (Bada et al. 2013, Bassey et al. 2021).

According to Amankwah et al. (2019) and Bakamwesiga et al. (2021), and the outcome shows that the dust produced during the operation is carried by the atmosphere and travels significant distances from the crusher and quarrying sites to the nearby communities. Table 8 shows that the list of equipment needed to operate a quarry varies according to production capacity.

The amount of air pollution depends on the local microclimate, the size, composition, and volume of dust in the surrounding air, and one of the main causes of air pollution is noise from quarry sites. For example, the mining and processing of granite produce silica dust (Loveson et al. 1997, Esguerra 2008, Doley et al. 2010, Eshiwani 2014, Amankwah et al. 2019).

Dust not only tends to accumulate on surfaces, making it unsightly, but it can also be harmful, especially to people who have respiratory problems. Dust can physically injure plants nearby by obstructing their internal organs and abrading their

Table 8: The minimum machinery and equipment required for quarrying operation (minimum production of 100 cubic meter) and impact on natural environment

Sl. No.	Type	Nos.	Size/ capacity	Make	Motive Power	Impact on natural environment
1.	Compressor	2	440 cfm	Atlas Copco	Diesel/ Electricity/DG	Air, noise, emission pollution
2.	Jack hammer	10	33mm dia.	Atlas Copco	-	Air, noise, dust pollution
3.	Hydraulic rock breaker/Excavator	2	1.2 cu. M or 380 HP	Sany – SY210C-9 or Tata Hitachi	Diesel	Air, noise, dust, emission pollution, ground vibration
4.	Tipper	2	20 tons	Tata	Diesel	Air, noise, dust, emission pollution, ground vibration
5.	Water tanker	1	5000 liter	Mahindra	Diesel	Air, noise, dust, emission pollution
6.	Tractor	1	04 tons	Mahindra	Diesel	Air, noise, dust, emission pollution
7.	JCB	1	----	JCB	Diesel	Air, noise, dust, emission pollution
8.	Diamond wire saw machine	2	40 and 60 hp.	---	Electricity	Air, water, dust pollution
9.	Quarry core drilling machine	1	---	---	Diesel/ Electricity/DG	Air, dust, noise, water pollution
10.	Diesel generator	2	320 KVA and 26 KVA	Cummins	Diesel/Electricity	Air, emission, noise pollution
11.	Accessories	---	All size drilling rods and other machine spare parts	----	---	---

leaves and cuticles. Dust may also have chemical effects that jeopardize the plants' long-term survival (Tiba 2017, Ogbonna et al. 2018, Timofeeva et al. 2022, Abdul-Wahab et al. 2022).

Quarry dust is linked to a multitude of leaf diseases, including abscission (early leaf fall), epinasty (bending of the leaf downward due to a faster rate of growth on the upper surface), necrosis (death of a portion of the leaf), and chlorosis (yellowing of the leaf due to loss or decrease of chlorophyll). Quarry dust is also a major source of air pollution (Sanjay Vediya 2014, Sayara et al. 2016, Sairanen et al. 2018 & 2019, Ekpa et al. 2022 & 2023, Opondo et al. 2023). According to Abayomi et al. 2014, Hamzart-Giwa et al. 2023, the quantity and quality of resource discovery, extraction, stonecutting procedures, and transportation to the final destination determine the impact on the air environment. According to Busuyi (2008), Olusegun et al. (2009), Akanwa et al. (2016 & 2017), Abhishek Pandey (2018) the rate of production and transportation also affects the intensity of these processes.

In the regions where stone crushing, quarrying, and stone processing are conducted, some of the sources of emissions or dust creation are as follows: dust from drill bits and blasting; dust from stone bodies and objects dug out and extracted. Transporting waste and dressing materials or processing materials from quarries to stockyards and disposal sites; loading, unloading, and moving finished items; and movement of vehicles on haul highways (Thompson et al. 1984, Iqbal et al. 2001, Moibi 2007, Ojeaga et al. 2023). A region's wind direction and speed have a direct bearing on the probability of dust pollution spreading in the study area.

The research area's major wind direction is west, and during the AAQ monitoring period, data on wind speed and direction were concurrently gathered. The ambient air quality of the research region has been evaluated using a network of twelve ambient air quality stations. The study region's meteorological characteristics were taken into consideration when building these stations, along with several other elements such as a densely populated area, industrial and residential development, and environmental sensitivity. It was noted that there are no ecosystems surrounding the intended exploratory well placements, and all of the wells are situated inside open spaces.

The principal inhabited the region and the predominant wind directions were considered when choosing the AAQ sites. Baseline ambient air quality evaluations provide information about the site's surroundings and are an essential component of research on environmental impact assessments. In addition to the impact of the surrounding topography, notable variations in the predominant winds and weather patterns are seen in the winter, summer, and post-monsoon seasons. A methodical program of air quality surveillance is used to evaluate the baseline air quality in the research region.

The quarrying site reported temperatures as high as 33°C and as low as 19°C during the research period. It was found that the quarry zone had an average temperature of 26°C. Throughout the trial, the average relative humidity ranged from 34% to 63%. In the Ramanagara District, there was some rainfall during the study period. There were five days of rain on average. The most rain that fell in March was 12 mm, while the least was 8 mm. The district receives roughly 931.58 mm of rain annually on average. During the winter monsoon, the majority of winds are north-easterly, whereas during the summer monsoon, they are south-westerly. During the three-month investigation, monthly wind speeds in the quarry zones ranged from 4.9 m/s to 5.6 m/s.

The AERMET data includes daily records for temperature, relative humidity, air pressure, solar radiation, precipitation, wind speed, and wind direction. AERMET reformats meteorological data to make it suitable for use as input in the AERMOD model (Neshuku 2012). The stone quarrying and stone-processing sectors won't alter the climate. When evaluating and keeping track of ambient air quality, soil and geological features are crucial.

Air Quality Index (AQI) Quantification

Monitoring sites have been reporting the ambient air pollution they have observed within a specific time frame (e.g., daily) by utilizing a grading system based on the AQI universal standard. The AQI is used to compare current pollution levels to ensure that impact reduction requirements are being followed and to increase public awareness of the risks associated with regular exposure to pollution. Even though the AQI is just a number that represents some aspects of air quality, to make its meaning clear to the general public, it is combined with various messaging, color schemes, graphics, and labels for the different categories of air quality (such as "good," "moderate," or "hazardous" as per CPCB (200) guidelines.

Based on a set of standards, the Air Quality Index (AQI) is an environmental indicator that provides information on the general condition and trend of the ambient air in a given area. This tool uses the weighted values of different air pollution parameters to create a single or multiple-number representation. The AQI is a useful tool for assessing and measuring the overall ambient air quality of a particular area since it accounts for the combined impact of all contaminants. The AQI can also be used to control equipment that, for example, raises the concentrations of some pollutants while reducing

Table 9: Air Quality Index grading system

AQI Value	Remarks	Health Concern
00 – 25	Clean air (CA)	None/minimal health effect
26 – 50	Light air pollution (LAP)	Possible respiratory or cardiac effect for most sensitive group, skin allergies, cough etc.
51 – 75	Moderate Air Pollution (MAP)	Increasing symptoms of respiratory and cardiovascular illness, skin allergies, cough, asthma, etc.
76 – 100	Heavy Air Pollution (HAP)	Aggravation of heart and lung diseases, asthma, eye irritation, skin diseases, etc.
> 100	Severe Air Pollution (SAP)	Serious aggravation of heart and lung Diseases, risk of death in children, asthma, cough, eye diseases, mental disorder etc.

others, or to create alternate strategies for preventing air pollution.

The AQI can be calculated using a variety of formulas and methods. Nonetheless, the following calculation has been used in this instance to determine the AQI value:

$$\mathbf{AQI = \frac{1}{4} \times (ISPM/SSPM + ISO_2/SSO_2 + INOx/SNOx) \times 100}$$

Individual measurements obtained during sampling that correlate to ISPM, IRSPM, ISO_2, and INOx are respirable particulate matter, suspended particulate matter, sulfur dioxide, and oxides of nitrogen, respectively. For ambient air quality, the Central Pollution Control Board of India (CPCB) has set SSPM, SRSPM, SSO_2, and SNOx criteria. Higher air pollution levels and associated health risks are correlated with higher AQI numbers. Table 9 lists the five categories that comprise the AQI scale. It outlines the range of air quality as well as any possible health hazards.

Examination of the Surrounding Air Quality in the Study Area

Sampling was done after GPS and remote sensing pinpointed the precise locations. Samples and measurements of the chemical components of atmospheric pollutants were taken at twelve different locations using an air particle counter and a fuel gas analyzer. Every location had an air particle counter accessible to measure SPM. The SPM concentration was printed and recorded by the instrument. A fuel gas analyzer was used to determine the extra air pollutants (NOx,

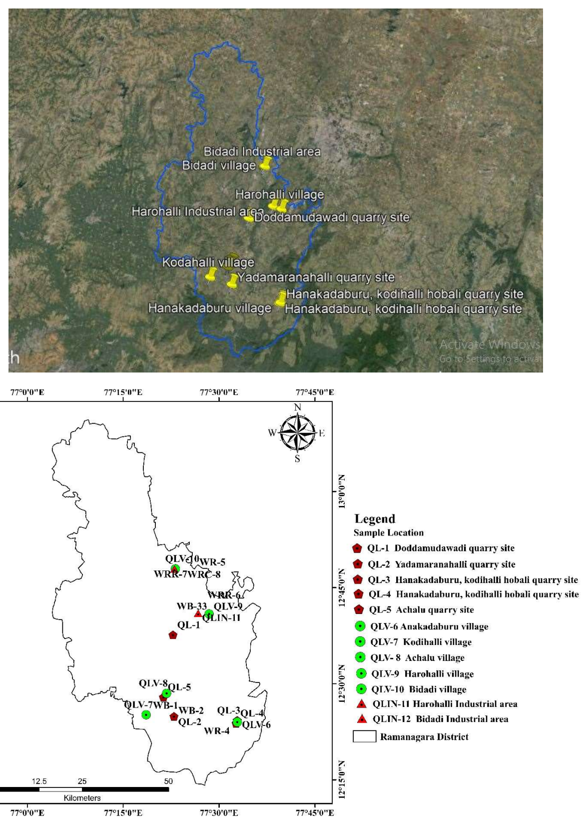

Fig. 5: Sites of ambient air quality monitoring.

Table 10: A summary of the results for ambient air quality.

Summary of Ambient Air Quality Results																								
Sample code number	PM10 µg/m3			PM2.5 µg/m3			SO2 µg/m3			NOX µg/m3			O3 µg/m3			CO mg/m3			NH3 µg/ m3	Pb µg/ m3	C6H6 µg/m3	C2OH12 ng/m3	As ng/ m3	Ni ng/ m3
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg	Max	Max	Max	Max	Max	Max
AAQ1	43.1	67.34	55.22	23.42	33.54	28.48	6.1	7.82	6.96	11.31	18.46	14.88	8.2	11.1	9.65	0.11	0.15	0.13	<5	<0.1	<0.1	<0.01	<1	<1
AAQ2	42.16	60.08	51.12	22.34	31.36	26.85	5.29	7.54	6.415	10.97	15.64	13.30	6.9	10.1	8.5	0.13	0.19	0.16	<5	<0.1	<0.1	<0.01	<1	<1
AAQ3	38.72	57.21	47.96	24.63	33.86	29.24	7.21	9.53	8.37	12.21	14.56	13.38	11.6	13.6	12.6	0.15	0.29	0.22	<5	<0.1	<0.1	<0.01	<1	<1
AAQ4	42.87	61.09	51.98	23.25	33.13	28.19	5.98	8.52	7.25	12.79	18.23	15.51	12.3	14.8	13.55	0.12	0.19	0.15	<5	<0.1	<0.1	<0.01	<1	<1
AAQ5	48.25	67.32	57.78	18.64	22.67	20.65	8.67	11.78	10.22	13.21	17.61	15.41	9.4	11.37	10.38	0.16	0.27	0.21	<5	<0.1	<0.1	<0.01	<1	<1
AAQ6	46.87	64.83	55.85	19.45	29.48	24.46	6.84	8.63	7.73	13.89	18.73	16.31	7.6	13.1	10.35	0.14	0.23	0.18	<5	<0.1	<0.1	<0.01	<1	<1
AAQ7	48.25	63.64	55.94	23.78	31.63	27.70	6.6	8.5	7.55	13.6	18.26	15.93	12.1	14.6	13.35	0.15	0.29	0.22	<5	<0.1	0.01	0.01	0.02	0.1
AAQ8	37.17	49.28	43.22	16.98	23.83	20.40	7.21	10.28	8.74	9.8	13.9	11.85	8.7	12.4	10.55	0.13	0.19	0.16	<5	<0.1	0.01	0.01	0.02	0.1
AAQ9	49.48	70.52	60	27.96	39.85	33.90	10.5	14.97	12.73	20.85	29.71	25.28	8.9	13.62	11.26	0.16	0.27	0.21	<5	0.05	0.01	0.01	0.02	0.1
AAQ10	45.48	64.82	55.15	24.52	34.95	29.73	6.95	9.9	8.42	14.1	20.1	17.1	10.4	12.79	11.59	0.15	0.31	0.23	<5	0.05	0.01	0.01	0.02	0.1
AAQ11	46.65	66.49	56.57	26.09	37.19	31.64	8.4	11.97	10.18	17.99	25.63	21.81	12.2	14.6	13.4	0.18	0.29	0.23	<5	0.05	0.01	0.01	0.02	0.1
AAQ12	47.84	68.18	58.01	26.26	37.34	31.8	9.76	13.91	11.83	20.17	28.75	24.46	12.8	15.37	14.08	0.17	0.32	0.24	<5	0.05	0.01	0.01	0.02	0.1
NAAQ standard - Industrial/ Residential/ Rural and Other Area	100 (24 Hours) (24 Hours)			60 (24 Hours) (24 Hours)			80 (24 Hours) (24 Hours)			80 (24 Hours) (24 Hours)			180 (1hour)			4 (1hour)			400 (24 hours)	1 (24 hour)	5 (Annual)	1 (Annual)	6 (Annual)	20 (Annual)

Note: BDL (Below detectable limit), DL (Detectable limit), BLQ (Below Detectable Limit), LOQ (Limit of Quantification) - Ammonia (µg/m3) – BDL (<5); Lead,(µg/m3) - BDL (<0.1). and BLQ (LOQ 0.05); Benzene, µg/m3 - BDL(<0.1) and BLQ(LOQ 1); Benzo[a] pyrene ng/m3 - BDL(<0.01) and BLQ(LOQ 1); Arsenic ng/m3 - BDL(<1) and BLQ(LOQ 2); Nickel ng/ m3 - BDL(<1) and BLQ(LOQ 10).

SOx, H_2S, and CxHx). The equipment was calibrated and constructed correctly, and additional equipment was utilized to print the read-off of the atmospheric concentration of each gas on a screen.

The direction and speed of the wind were measured using an electrically powered digital anemometer. The selection criteria for monitoring locations include the following: topography and terrain; meteorological circumstances (both upwind and downwind locations); residential and sensitive areas within the study area; regional baseline air quality and pollution levels; and representation of possibly impacted areas.

Throughout one (1) season or three months (January 2024 to March 2024), the ambient air quality in the research region was measured twice a week by the NAAQS for twelve parameters (PM_{10}, $PM_{2.5}$, SO_2, NOx, CO, O_3, Pb, NH_3, C_6H_6, C_2OH_{12}, As, and Ni). The Central Pollution Control Board's (CPCB) monitoring criteria were followed when sampling was done at each location. PM_{10}, $PM_{2.5}$, SO_2, NO_x, CO, Pb, O_3, NH_3, C_6H_6, C_2OH_{12}, As, and Ni, maximum values at all study locations are well under the National Ambient Air Quality Standards for residential, commercial, and industrial areas (Tiwari et al. 2012).

Throughout the study, the average baseline levels of PM_{10} (37.17 to 70.52 µg/m^3), $PM_{2.5}$ (16.98 to 39.85 µg/m^3), SO_2 (5.29 to 13.91 µg/m^3), NOx (9.8 to 29.71 µg/m^3), CO (0.15–0.32 mg/m^3), O_3 (6.9 to 15.37 µg/m^3), and some BDL and LOQ were found to be well within the National Ambient Air Quality Standards for both commercial, residential and industrial areas. Places to monitor ambient air quality are depicted in Fig. 5. The observed data for each location was used to calculate several measures, including the maximum, minimum, and average.

Findings from the Analysis of Ambient Air Quality

The quarrying and stone processing industries are known to produce air pollution issues due to many reasons, such as truck traffic, blasting, and drilling. Small-scale quarrying is unlikely to significantly impact the current air quality in the core zone. Using environmental controls in a way that reduces the likelihood of contamination is necessary to reduce air pollution. The test results that are enclosed concern the surrounding area and ambient air quality at the quarry. Using the observed data for each location, several metrics were computed, including the maximum, minimum, and average. The overall summary of the ambient air quality test findings is shown in Table 10. Fig. 6 shows that the graphical representation of air quality monitoring results.

Observations in the Sampling Areas

PM_{10} concentrations were measured to be at a maximum of 70.52 µg/m^3 and a minimum of 37.17 µg/m^3 respectively. The village of Harohalli had the highest concentration, while the village of Achalu recorded the lowest. The range of average values was 43.225 µg/m^3 to 60.00µg/m^3. The $PM_{2.5}$ values were measured to be 39.85 µg/m^3 at the maximum and 16.98 µg/m^3 at the minimum. The village of Harohalli had the highest concentration, while the village of Achalu recorded the lowest. The measured average values fell between 20.655 µg/m^3 to 33.905 µg/m^3. The measurements of SO_2 concentrations at the maximum and minimum were 13.91µg/m^3 and 5.29µg/m^3 respectively. The

Fig. 6: Graphical representation of air quality monitoring results.

Bidadi industrial sector recorded the highest concentration, while the Yadamaranahalli quarry site recorded the lowest. The measured average values fell between the ranges of 6.415 $\mu g/m^3$ to 12.735 $\mu g/m^3$. There was a maximum of 29.71 $\mu g/m^3$ and a low of 9.8 $\mu g/m^3$ for the concentration of NOx. The settlement of Achalu village recorded the lowest concentration, while the village of Harohalli recorded the largest concentration. From 11.85 $\mu g/m^3$ to 25.28 $\mu g/m^3$, the average levels were found to be present.

The observed CO values were 0.32 mg/m^3 at the maximum and 0.15 mg/m^3 at the minimum. The Doddamudawadi quarry site had the lowest concentration, whereas the Bidadi industrial area had the highest concentration. It was noted that the average values fell between 0.13 mg/m^3 and 0.245 mg/m^3. The reported values for O_3 concentrations were 15.37 $\mu g/m^3$ for the maximum and 6.9 $\mu g/m^3$ for the minimum. The Bidadi industrial sector had the highest concentration, while the Yadamaranahalli quarry site recorded the lowest concentration. The observed average values fell between 8.5 $\mu g/m^3$ and 14.08 $\mu g/m^3$. The Central Pollution Control Board's (CPCB) guidelines for industrial, rural, residential, commercial, and other areas are well under the limits in the research sites, while the concentrations of NH_3, Pb, Ni, As, C_6H_6 and C_2OH_{12} were all below detectable levels at all locations.

Numerous factors and parameters, such as the climate, topography, extent and method of quarry operation, use of equipment and machinery, population density, density of highly polluted industrial areas, density of road vehicles, density of forest fires, density of vegetation, and so on, affect the distribution of the aforementioned chemical elements in different quarry locations, local areas, residential areas, and industrial areas. Air pollution levels are higher throughout the entire area as a result of the previously described factors. The observation detailed the areas where the lower and higher levels of air pollution were spreading at the sampling locations.

Air Pollution Effects on Human Health

Quarrying is viewed as essential to human survival on a global scale. This is because it has contributed to the growth and development of every country, region, and sub-region. As a result, it is easier to build concrete structures, and the state's road and bridge infrastructure is developed, both of which have a significant positive economic impact on the nation (William et al. 2006, Sahu et al. 2018, William 2020). Furthermore, it produced jobs that were both direct and indirect, which made it easier for individuals to find work and support themselves (Peter et al. 2018, Samba et al. 2022). The study found that because it gave individuals economic power and maintained their well-being, quarrying was an especially sustainable industry (Ako et al. 2015, Ugbogu et al. 2009). This implies that, in addition to agriculture, quarrying provides a sizeable portion of the local population's income (Fugiel et al. 2017, Yasobant et al. 2017).

The local people, the environment, wildlife, workers, the population's socioeconomic situation, health, and society are all impacted by the various barriers, problems, and challenges that come with stone quarrying (Nartey et al. 2012, Turyahabwe et al. 2021). These problems include changes in topography, degradation, and abandonment of land, loss of ecosystems and biodiversity, emissions, noise and dust pollution, air pollution, and water pollution, including the release of ionizing radiation into the atmosphere (Sanjay Vediya 2014, Pal et al. 2019). These results indicate that places that were productive in the past have become unproductive, which is upsetting the ecosystem as a whole.

Deforestation and land degradation therefore affect biodiversity (Rani et al. 2017). Due to their role as mosquito habitats and rain-retaining materials, open quarries and deforestation have been associated with an increase in non-communicable diseases, including malaria. This also affects the cost of buying and selling real estate (Owolabi et al. 2020).

The results of the study show how much dust is produced throughout several stages of the quarrying process, including drilling, stone blasting and crushing, loading, and transporting the finished products. The larger dust particles settle close to one another, while the thinner ones spread out widely, depending on the direction and speed of the wind. Different levels of particulate matter (PM) are produced based on its size, which also affects how long and how far it travels when suspended in the air (Romo-Kroger et al. 1989, Pradhananga et al. 2020).

Based on their aerodynamic diameter, the sizes are divided into $PM_{2.5}$ (equal to or less than 2.5 micrometers) and PM_{10} (equivalent to or fewer than 10 micrometers) particles. The average diameter of human hair is between 50 and 70 µm; therefore, these sizes are less than that (Ogbonna et al. 2020, Chamdimba et al. 2023). Dispersed particulate matter can cause several issues, depending on its size. According to William (2020) and Ekpa et al. (2022 & 2023), for example, it can lead to poor visibility near quarry and crusher units, reduced agricultural yields because dust cover on plant surfaces blocks light needed for photosynthesis, ophthalmic disease because particulates carry pathogens, and respiratory disorders in humans and animals.

It is common knowledge that employees in quarries disobey health and safety; laws. People often forget to wear safety gear, like dust masks, helmets, and appropriately

Fig. 7: The safety and health conditions of the workers at the quarry sites and field visit images from several quarries and crusher unit.

protected clothing (Sanjay Vediya 2014, Sayara et al. 2016, Hassan 2023). As a result, they come into contact with small dust particles. Their health is consequently adversely affected (Vandana et al. 2020, William et al. 2006). Numerous health problems, including lung infections, skin and eye infections, respiratory and pulmonary disorders, and lung collapse, can be brought on by dust exposure (Ndinwa et al. 2014, Mbandi 2017, Nemer et al. 2020).

The Ramanagara district quarry workers found that their lack of protective gear and the dust from the quarries had caused respiratory difficulties. In addition to dyspnea, these symptoms before and after the quarry operation include coughing, wheezing, asthma, headaches, eye issues, chest discomfort, heart problems, mental stress, throat infections, allergies, and skin disorders (Sinha et al. 2000, Singhal et al. 2022, Abeya 2023). Based on the previously indicated facts-that dust is irksome, that dust has an impact on health, and

Table 11: The summary of air pollution impacts on human health

Pollutants	Environmental impacts on human health
Ozone (O_3)	Ozone is linked to brief effects on the respiratory system in humans especially asthma, including reductions in pulmonary function in those engaging in mild to moderate exertion., various diseases and early mortality. Ozone depletion damages vegetation and reduces visibility, among other negative effects.
Particulate matters ($PM_{2.5}$ & PM_{10})	Particulate matter has varying effects on health, and as particle size drops, so does the likelihood that the particle will have an impact on human health. Particles smaller than 1 µm entered the lower parts of the lungs, while larger particles lodged in the throat and nose, measuring more than 10 µm. Death, both acute and chronic bronchitis.
Sulphate (SO_4)	Chest troubles, respiratory disorders, mild RADs, days missed from work, and moderate to severe asthma symptoms are all examples of lower and upper respiratory illnesses.
Carbon monoxide (CO)	As a result of its interaction with hemoglobin in human blood, it lowers the blood's transport of oxygen. When CO levels are high, those who have cardiovascular illness or chronic heart disease may feel pain in their chest. Reduced delay to angina onset, hospital admissions, mortality, and congestive heart failure. CO can cause unconsciousness and death, damage manual dexterity and vision.
Nitrogen oxides (NO_2)	Short- and long-term impacts of nitrogen dioxide on human health are evident; children's respiratory disorders are more common in the former case, while the latter reduces immunity to respiratory infections. In addition to lowering auxiliary beat frequency and increasing permeability of cell membranes, NO_2 exposure also makes asthmatics more sensitive to respiratory infections and inhaled allergens.
Sulphur dioxide (SO_2)	Another gas that negatively affects human health is sulfur dioxide, since it can have a severe effect on the respiratory system. Asthma sufferers' lung function is altered by the emission, which is directly correlated with fuel's sulfur content. Sensitive people's respiratory symptoms are made worse. Respiratory symptoms, alterations in pulmonary function, and morbidity among asthmatics who exercise.
Lead (Pb)	Deaths, high blood pressure, non-fatal heart attacks, non-fatal strokes, and declines in IQ.

that rain-covered roofs are unclean-the impact of quarrying on human health is examined. The safety and health conditions of the workers at the quarry sites are depicted in the Fig. 7, which also include field visit images from several quarries and crusher unit.

The results demonstrated that all respondents (100%) considered noise and dust to be health hazards and a major source of annoyance. Dust almost always contaminates rain that falls from roofs. Additionally, every respondent mentioned that noise, dust, water, and floodwaters could be connected to their on-going health issues. Numerous illnesses and health problems are signs of the detrimental impacts of stone processing and quarrying, particularly for the villages close to crushers. There is also a connection between acid rain and quarrying (Maduka et al. 2014, Boutemedjet et al. 2019).

According to the study, acid rain is known to damage plants, worsen air pollution, and sicken people and animals brought on by quarrying. There are several quarrying-related health risks. An analysis showed a connection between the vibrations caused by quarrying and fractures. This could lead to building collapses, which would cause fatalities and injuries. When asked how they felt about the quality of the air right now, respondents said that 24% thought it was poor and 76% said the stone-cutting and quarrying sectors should be held accountable. Since the quarry owner is providing benefits, the majority of respondents chose not to react. Thus, it seems logical that stone-cutting and quarrying have an impact on air quality. Table 11 provides a summary of how typical air contaminants affect human health.

TECHNIQUES FOR MITIGATION AND CONTROL MEASURES

The following mitigation and control techniques, corrective measures, and remedies have been suggested for the granite quarrying and stone processing industries: a sizable buffer zone, or "green belt," ought to be created surrounding the industrial area. Providing dust masks for laborers. Allowing the staff to don the appropriate personal protective equipment. Avoid overcharging blast holes by using controlled blasting techniques. It is advisable to regularly monitor the quality of the surrounding water, air, and noise. It is also suggested that you use effective, quiet equipment. Hazardous places should be avoided, and signboards displaying instructions should be posted.

Dust pollution will be managed with the use of electrostatic precipitators. By using silica in water quarrying and groundwater dust control systems, silica-related problems can be minimized. At sensitive locations, such as haul roads, crusher and screening plants, mineral handling facilities, quarrying facilities, and stone processing plants, dust suppression is enforced using heavy dust sprinklers and road watering trucks. Mineral handling, HEMM, crushing, and screening equipment must be provided in dust extraction facilities. Hoods, water sprays, and dust collectors are helpful pieces of equipment for controlling drilling dust. Moreover, suitable chute design, vulcanizing conveyor belt joints, under-belt cleaning equipment, hoods, transfer points, and dust suppression and/or extraction systems for conveyors are frequently employed as dust pollution management techniques. Enclosures used in mineral handling plants must be well secured.

All vehicles, including trucks, dumpers, and transport vehicles, must be leak-proof. Use the proper components when spraying to stop dust from flying. Highways and other roads should be adequately coated with chemical additives to successfully limit dust emissions. Haul roads and service roads should be graded regularly. Haul roads should also have any loose dirt and collected dust removed. Appropriate maintenance, such as checking exhaust emissions and establishing speed limitations on the cars and earthmoving equipment. When transporting stone products, make sure tippers and dumpers are not overloaded, and cover heavy tippers with tarpaulins.

Utilizing vegetation to stabilize significant regions that generate dust and waste yards. Reduce the number of open regions and seal off the area used for stone quarrying and processing to reduce the amount of dust produced. Ideal enclosed areas for equipment and supply storage for building projects. Utilizing and maintaining machinery and equipment efficiently to lower air emissions, noise pollution, and energy use. The exhaust vent of the DG set will have enough stack height to ensure that gaseous emissions diffuse rapidly. Vehicles must receive routine maintenance and oversight to guarantee that their fuel usage and emissions are within permitted limits. Inspecting construction sites, stone processing plants, and quarry activities regularly to ensure that waste debris is promptly removed and disposed of in landfills, recycled, or used in other ways. Grading transport and service roads and removing accumulated dusty material regularly.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

We start with an analysis of the field work, laboratory and desk work data in order to track the quality of the air in the Ramanagara district. Twelve metrics, including $PM_{2.5}$, PM_{10}, SO_2, NOx, CO, O_3, Pb, NH_3, C_6H_6, C_2OH_{12}, As, and Ni, were monitored twice a week for three months (January

2024 to March 2024) by the National Ambient Air Quality Standards (NAAQS) in the study area. This indicates the greater distance that the air quality covers. According to the Central Pollution Control Board (CPCB) monitoring recommendations, sampling was carried out at each location. The NAAQS in the research area measured twelve metrics twice a week for one (01) season, or three months (January 2024 to March 2024), including PM_{10}, $PM_{2.5}$, SO_2, NOx, CO, O_3, Pb, NH_3, C_6H_6, C_2OH_{12}, As, and Ni. The findings showed that SPM is high in every station, even if SO_2 and NOx levels are within allowable bounds in all measured locations. The study found that the average baseline levels of PM_{10} (37.17 μg/m^3 to 70.52 μg/m^3), $PM_{2.5}$ (16.98 μg/m^3 to 39.85 μg/m^3), SO_2 (5.29 μg/m^3 to 13.91 μg/m^3), NOx (9.8 μg/m^3 to 29.71 μg/m^3), CO (0.15 mg/m^3 to 0.32 mg/m^3), O_3 (6.9 μg/m^3 to 15.37 μg/m^3), and NH_3, Pb, Ni, As, C_6H_6 and C_2OH_{12} were below detectable limit (BDL) and limit of quantification (LOQ) are all well within the National Ambient Air Quality Standards for commercial, industrial, and residential areas at all monitoring locations for the duration of the study. Apart from the environment, they can also have a major detrimental impact on infrastructure, transportation, agriculture, population density, mining, quarrying, human health, etc. The research areas' stone-processing and granite-quarrying businesses don't significantly harm the air quality. The distribution of air quality source potential in Ramanagara district was evaluated in this research work.

Recommendations

1. Environmental preservation is of utmost importance to the stone quarrying and processing industry. The business will abide by all environmental regulations. A well-manicured greenbelt will be preserved by the quarry operation. Furthermore, all environmental statute standards shall be continuously implemented and upheld.
2. By introducing both natural and artificial techniques to stop the spread of dust in the neighborhood, air pollution caused by billowing dust can be avoided. One way to lessen the harm that the dust from the quarries causes to the environment is to plant densely packed, quickly growing trees around the quarries and on any reserved area they own. The same quickly growing trees with dense foliage should also be added to the proposed buffer zone to increase its density. Rather than using corrugated sheets attached to the side of crushing plants in certain quarries, man-made and natural solutions can be implemented to reduce the amount of dust that blows into the area, thereby mitigating the problem of air pollution caused by billowing dust.
3. In order to improve the green canopy, prevent the spread of dust and other airborne pollutants, stop soil erosion, stop land degradation, and address other issues, reforestation is mandated by the quarrying and stone processing industry plan.
4. There should be frequent environmental audits carried out on all the quarries within the research area. In order to evaluate the effectiveness of the quarries' conservation or anti-pollution program, a methodical analysis of their interactions with the environment is conducted.
5. Regular health awareness efforts should also be conducted to inform the public about the possible dangers of unhygienic surroundings. To help enhance the health status of its residents, the local government should mandate frequent health assessment studies.
6. Local government agencies should be held to a higher standard of accountability and should take an active role in resolving public complaints regarding the detrimental effects of the granite business. Steer clear of quarrying in environmentally vulnerable areas.

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